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DIRECT-INJECTION TRACTOR DIESELS IN THE USSR

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Diesel tractors consume approximately 30 percent less fuel than tractors with carburetor engines. The USSR leads the world in diesel tractor output, and the three basic mass production tractors, the S-80, the DT-54, and the D-35, are equipped with diesels. Work is in progress to construct three new tractor diesels, and putting them into production will complete the dieselization of all the basic types of USSR tractors. The next problem for the automobile and tractor industry is to reduce the special fuel consumption of the tractor diesels it puts out.

To assure a long life for the engine, the method of mixing the fuel was chosen to produce low maximum pressure in the cylinders and a slow increase in pressure as the fuel burns. Among the methods of mixing employed is the precombustion process, used in the KDM-46 diesel of the S-80 tractor and the turbulence chamber, used on the diesels of the KD-35 and DT-54 tractors. In the precombustion process, the fuel and air are mixed in the combustion chamber above the piston by utilizing the energy of the gases from an initial portion of fuel burned in the precombustion chamber. However, the overflow of gases through the narrow opening of the precombustion chamber produces losses which increase specific fuel consumption. Mixing the fuel in a turbulence chamber by the creation of vortical currents also produces losses due to the overflow of gases through the passages joining the turbulence chamber to the space over the piston.

Losses due to overflow of gases for the Kirovets D-35 tractor, as determined by NATI (Scientific Automobile and Tractor Institute) were 2 horsepower, or 0.32 kilogram per square centimeter, at 1,400 revolutions per minute. Increasing the surface of the walls of the combustion chambers leads to a slight increase in the loss of heat during combustion.

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Mixing may be improved by decreasing the volume of the precombustion chamber. According to NATI, replacing the present turbulence chamber of the D-35 tractor, which constitutes 69 percent of the compression chamber volume, by a turbulence chamber constituting 52 percent of the compression chamber volume reduces the specific fuel consumption of the engine by 7 g/e.l.s.ch. [grams/unit horsepower-hour?]. This does not increase the maximum pressure of combustion or the rate of pressure increase during combustion.

The direct-injection method eliminates losses which are due to overflow of gases, and considerably reduces heat losses during combustion owing to the reduction of the surface of the combustion chamber walls. However, direct injection not only increases the maximum combustion pressure, but also the rate at which pressure increases in the cylinder during combustion. This puts increased demands on the fuel apparatus, which should produce even distribution of the atomized fuel in the combustion chamber. To facilitate combustion, the fuel must be atomized more finely, which in turn calls for greater spraying pressure.

Of late, direct injection has been adopted in automotive and tractor diesels. There has been widespread research on the construction of direct-injection automotive and tractor diesels in the USSR. In England, 19 of the 38 automotive diesels put out in 1950 were of the direct-injection type. In the field of tractor diesels, direct injection is used in English (Albion, Rolls-Royce), Italian (Fiat), and German (MAN) models. Of special interest is the MAN diesel, whose specific fuel consumption is 17[illegible] g/e.l.s.ch. However, tests conducted by NAMI (Scientific Research Automobile and Automobile Motor Institute) and VNIDI (All-Union Scientific Research Diesel Institute) showed that the fuel economy of this machine is counterbalanced by stiffness of operation. The maximum combustion pressure of the MAN engine reaches 70-75 kilograms per square centimeter, and the rate at which pressure increases in the cylinder during combustion is about 8-9 kilograms per square centimeter per degree of rotation of the crankshaft. This engine uses an open combustion chamber which is in the form of a sphere located in the piston. The volume of this chamber is 85 percent of the total volume of the compression chamber. An enclosed injector with the needle set in the face is used to spray the fuel. The fuel is fed at high speed, and only during a period equal to the time it takes the crankshaft to turn through [illegible] degrees. It must also be noted that the low fuel consumption of this diesel is coupled with high coefficient of mechanical efficiency, equal to 0.85.

One of the means of eliminating the shortcomings of direct-injection diesels is to use a two-phase injection, such as that proposed by engineer A. Charomskiy. In this method, a small amount of fuel is first fed into the cylinder. This initial charge is prepared for combustion and begins burning just as the second, main charge of fuel enters the cylinder. This brings about the gradual combustion of the main charge and a slow increase in pressure during combustion. The rate at which pressure increases may be hastened by choosing the rate at which the main charge is fed. Models of simple, reliable two-phase injection equipment have appeared, and they are beginning to be applied in direct-injection diesels. The double injection is effected by one sprayer during one stroke of the fuel pump plunger, without complete stoppage of the flow of fuel between the first and second stages. In the first stage, the fuel is injected slowly, so that only about 25 percent of the total charge enters the cylinder during the period of induction (retard of ignition). The rapid combustion of this amount of fuel does not bring about any considerable increase in pressure. In the transition to the second phase, the fuel is fed more rapidly, but burns as fast as it is injected, making it possible to control the combustion process.

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Figure 2 [see appended list of figures] shows two indicator diagrams made under ordinary injection (dotted curve) and two-phase injection (solid curve), from which it is evident that the rate of pressure increase is reduced and the maximum pressure in the cylinder is somewhat lower with two-phase injection.

Figure 3 shows an injector suitable for two-phase injection which operates in conjunction with an ordinary pump. The fuel is fed to the injector through a high-pressure pipe which is joined to the sprayer by a flanged socket screwed into opening 1. The fuel flows along the passage 2 into chamber 3 and annular space 4. Having passed through the pressure valve 5, passage 6, and center hole 7, the fuel enters the first phase of the spray holes of sprayer 8, located on the tip of the injector. As the pump increases the speed at which fuel is fed, the shutoff plunger 9, held down by spring 10, rises and opens hole 11. Then the fuel also passes through passage 12, through the second pressure valve 13, through passage 14, through the groove in rod 15 and into the annular space 16, which is joined to the main spray holes. Thus, after shutoff plunger 9 is raised, all the spray holes of the injector go into action, and the rate of delivery of fuel to the combustion chamber increases. The relations between the quantity of fuel injected during the first and second phases, and the choice of the moment when the phases begin, can be controlled by the number and dimensions of the spray holes and the characteristics of the shutoff plunger spring. The use of pressure valves facilitates prompt fuel cutoff, which in turn improves the combustion process and increases the life of the sprayer.

A second type of two-phase injector employs a special cam (whose profile is shown in Figure 4) in the fuel pump. The rate at which fuel is fed into the cylinder with respect to the angle of rotation of the crankshaft is shown in Figure 5. An ordinary sprayer cannot be used in this system. Since the injection of fuel in the first phase is at low speed, the sprayer should start opening at low pressure. At the same time, the sprayer needle should be seated under high pressure to cut off fuel supply promptly. To accomplish this, a staggered needle (Figure 6) with ground collars is used. These collars form two annular spaces in the body of the sprayer. The upper space 3 is connected by groove 5 directly to supply channel 6. Lower space 4 is connected to this same channel 6 through shutoff valve 7 and through the seating collar of needle 8 with the spray holes. The needle is kept seated by spring 9. When the pressure of the fuel in supply channel 6 increase, forces arising in spaces 3 and 4 compress the shutoff valve 7 spring slightly without hindering the flow of fuel from the supply pipe to the lower space. The main spring 9 is so regulated that the needle starts to rise at a fuel pressure of 70 atmospheres. As the needle rises, the force compressing the spring increases, since the pressure of the fuel is transmitted to the face of the needle under its seating collar 8; consequently, seating of the needle should take place under a lower pressure than that at which it began to rise. To increase the pressure with which the jet is shut off, a shutoff valve is used to cut off the lower recess from the supply channel when the fuel supply is cut off by the pump. This assures firm seating of the needle when there is greater fuel pressure in the system.

The application of new processes and materials to increase the strength and wear resistance of tractor diesels will also facilitate the adoption of the direct-injection method. The use of crankshafts with surface hardened journals, three-layer bushings of the interchangeable type, and other improved techniques permit operation of the diesel engine under increased pressure and a faster rate of pressure increase.

It must be noted that there is no experimental data on the effects of pressure and the rate of pressure increase on the life of the engine, and practical testing may show that the dangers of using direct injection in tractor diesels have been exaggerated. Similarly, the reliability of the fuel apparatus under the severe conditions created by the direct-injection process can only be evaluated by practical testing. The considerable advantage that this process has in fuel economy demands accelerated research work on its application in tractor diesels. Comparative field testing of a series-produced tractor diesel with a turbulence chamber and the same tractor with direct injection into the chamber over the piston should be included in this research.

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